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EQUIPMENT FOR CITY MILK PLANTS[1]

By C. E. CLEMENT, *Associate Market Milk Specialist*, and F. M. GRANT, *Assistant Market Milk Specialist, Division of Market Milk Investigations, Bureau of Dairy Industry*

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SELECTION OF EQUIPMENT

Before making plans for the establishment of a new milk plant or the rearrangement of an old one the amount and type of equipment to be used should be decided upon. Too much or too complicated apparatus is often provided. In many cases the capacity of the machines is either too great or too small for the quantity of milk to be handled. Such mistakes are usually detected after it is too late. The following points should be considered when selecting the equipment:

Simplicity. The equipment should contain the fewest number of parts to do the required work efficiently.

Ease of cleaning and sterilizing. It is important that all milk apparatus be cleaned and sterilized daily. If this work is to be done easily and properly the equipment must have few inaccessible parts.

Ease and economy of operation. Unless a machine can be operated economically it will be a liability to the owner rather than an asset. If it can be operated easily, comparatively little attention to it will be required.

Durability. Apparatus of poor quality usually is costly in the end; durability is an important factor.

Initial cost. Although cheap apparatus seldom proves satisfactory, it is not always necessary or advisable to buy the highest-priced equipment. The initial cost, however, is an important factor to be considered.

Proper capacity. The equipment should be of sufficient capacity to handle all probable increase of business. Milk-plant equipment, however, depreciates rapidly, and it is therefore not advisable to procure oversize apparatus which will not last until the anticipated increase has taken place.

Proper material. All apparatus with which milk comes in contact must be of a material that will not impart a metallic or off flavor to the milk and will not result in any chemical or electrolytic action. Tinned copper and glassenameled and nickel equipment are satisfactory and are most commonly used. Some other metals and alloys which have been used in recent years have proved satisfactory.

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[1] This circular supersedes U. S. Dept. Agr. Bul. No. 890, Milk Plant Equipment.

DEPRECIATION OF EQUIPMENT

The life of milk-plant equipment depends upon the original condition, amount of use, and the care given it. As a rule it receives hard and constant usage and depreciates very rapidly. Furthermore, improvements in milk-plant equipment are constantly taking place. It, therefore, becomes obsolete after a few years and must be replaced by more modern equipment.

Table 1 gives a tabulation of the replies to a questionnaire sent to 267 milk-plant operators regarding the average annual depreciation of various pieces of equipment at their plants. With the exception of the power-plant equipment, the most common depreciation for the different equipment was from 15 to 20 per cent per year. The most common depreciation for bottle fillers was 20 per cent. In most plants, therefore, this equipment will last only about five years before it must be replaced. Bottle washers last slightly longer, 16.6 per cent being the most common depreciation. Fifteen per cent annual depreciation was most commonly given for pasteurizing apparatus, and many plants have as low a depreciation as 10 per cent. Power-plant equipment generally lasts longer than other equipment required for milk plants because it is more durable and does not become obsolete so quickly. Ten per cent per year was most commonly given as the depreciation for this class of equipment.

TABLE 1.—*Annual depreciation of various pieces of equipment at milk plants of different sizes*

Number of gallons of milk handled daily	Total number of plants	Per cent annual depreciation of—											
		Bottle washers			Bottle fillers			Pasteurizer and cooler			Power-plant equipment		
		Average	Range	Most common	Average	Range	Most common	Average	Range	Most common	Average	Range	Most common
500 or less	30	14. 8	10–25. 0	10. 0	15. 7	10–33. 3	20	14. 5	8.5-25.0	10. 0	12. 4	5–25	10
501 to 1,000	27	15. 1	5–25. 0	15. 0	15. 0	8–25. 0	20	14. 0	10–20. 0	10. 0	13. 0	5–25	10
1,001 to 2,000	39	15. 9	5–25. 0	15. 0	17. 3	8–25. 0	20	15. 3	5–25. 0	15. 0	13. 6	8–25	10
2,001 to 3,000	26	14. 8	6–25. 0	15. 0	15. 9	10–25. 0	20	13. 9	6–25. 0	15. 0	12. 2	6–20	10
3,001 to 5,000	43	15. 8	7–25. 0	16. 6	18. 5	7–50. 0	20	15. 8	7–25. 0	16. 6	12. 3	5–24	10
5,001 to 10,000	56	15. 9	7–30. 0	20. 0	17. 5	10–30. 0	20	15. 3	8–25. 0	15. 0	11. 3	5–25	10
10,001 to 20,000	26	16. 2	10–25. 0	16. 6	19. 6	10–33. 3	20	16. 0	10–25. 0	20. 0	12. 1	6. 5–25	10
Over 20,000	20	16. 0	10–33. 3	16. 6	18. 4	12. 5–33. 3	20	15. 8	8–33. 3	16. 6	9. 7	5–15	10
Total or average	267	15. 6	5–33. 3	16. 6	17. 3	7–50. 0	20	15. 1	5–33. 3	15. 0	12. 1	5–25	10

EQUIPMENT REQUIRED

In general, the following list represents the principal equipment required for the typical city milk plant:

Weigh can and scales.
Can washers.
Receiving vat.

Storage tanks or vats.
Clarifier or filter.
Pasteurizing and cooling equipment, with apparatus for controlling and recording the temperatures.
Fillers and cappers.
Bottle washers.
Sanitary milk pumps, piping, etc.
Labor-saving devices, such as conveyors and elevators.
Boilers, engines, refrigerating machinery, motors, etc.
Cans, bottles, crates, etc.

WEIGH CAN AND SCALES

At very small plants the milk may be weighed in the cans in which it is received, in which case the weigh can itself will not be needed.

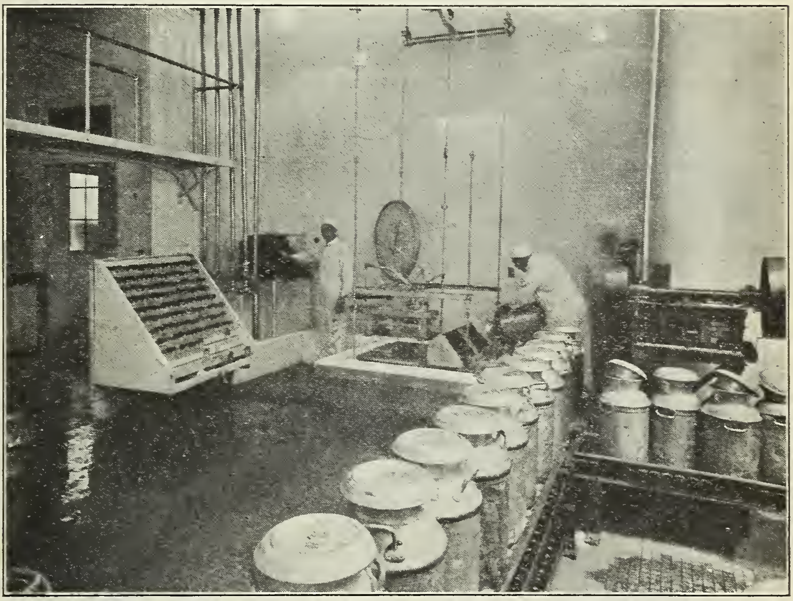

FIGURE 1.—Weigh can and scales in use. (Sample rack at left)

At medium-sized and large plants either a single or double compartment weigh can may be used; but when milk is received from a large number of producers much time may be saved by the use of a double-compartment can. The valves through which the milk is released from the weigh can should be large so that the milk will run out quickly and the operator will not be delayed by waiting.

In all cases, whether milk is bought by the gallon or by the pound, it should be weighed. If it is bought by the gallon the weight may be readily converted to gallons; in fact, there are scales on the market which record the quantity in gallons as well as in pounds. One company handling a little more than 4,000 gallons of milk daily decided after several years to buy the milk by weight. Scales were installed, and the difference between the measure by the cans and the actual quantity of milk received, as shown by the scales, was determined. Table 2 shows that if the plant had bought the milk by can measure it would have paid for more than 2,000 gallons of milk above what it actually received in each of the two months. This would have been a loss of more than $600 a month, if milk was worth 30 cents a gallon.

TABLE 2.—*Difference between can measure and actual quantity of milk received as shown by scales at a city plant*

Item	Milk received during April	Milk received during May
	Gallons	*Gallons*
Can measure	126, 460	138, 485
Weight	124, 331	135, 941
Difference	2, 129	2, 544

Inaccuracies which result from receiving the milk by measure instead of by weight are due principally to the following causes: Cans not filled by producer, milk spilled or leaked in transit, and use of cans not holding the required amount because of dents or other defects.

After the milk of each producer is emptied into the weigh can a sample is taken for the purpose of determining the butterfat content. A sample rack is shown in Figure 1, and laboratory equipment for determining the butterfat content is shown in Figure 2.

CAN WASHERS

In washing cans first rinse them in cold water to remove milk adhering to them, then wash them in hot water containing a washing powder, rinse in hot water, steam, and dry. In small plants the cans may be washed as follows: After being rinsed in cold water they are immersed in a tank containing a hot washing solution. They are then washed inside and outside with a brush, after which they are transferred to another tank and rinsed in clean hot water. Finally, they are placed over a jet through which hot water and steam are forced into them. Each can should be steamed at least 30 seconds, or until it will dry immediately. Very satisfactory results may be obtained with this system of washing cans if the work is properly done.

Large plants must have can washers that are as nearly automatic as possible and in which a large number of cans can be washed in a short time. The so-called hydraulic can washer (fig. 3) is most commonly used. This washer consists of a series of tanks containing alkali powder washing solutions and rinsing waters. As the cans travel in an inverted position through the machine they pass over a series of jets through which the washing solutions and rinsing waters are forced from the tanks below by means of powerful pumps. Next they pass over steam jets through which live steam is blown into them. The next step is the drying of the cans, which is accomplished by a blast of hot air generated by blowing air through a chamber containing steam pipes. The drying of the cans is very important, for it not only improves their sanitary condition but also prevents rust and thus prolongs their usefulness. The hydraulic can washers may be of either the straightaway or the circular type, the latter having the advantage of requiring less floor space.

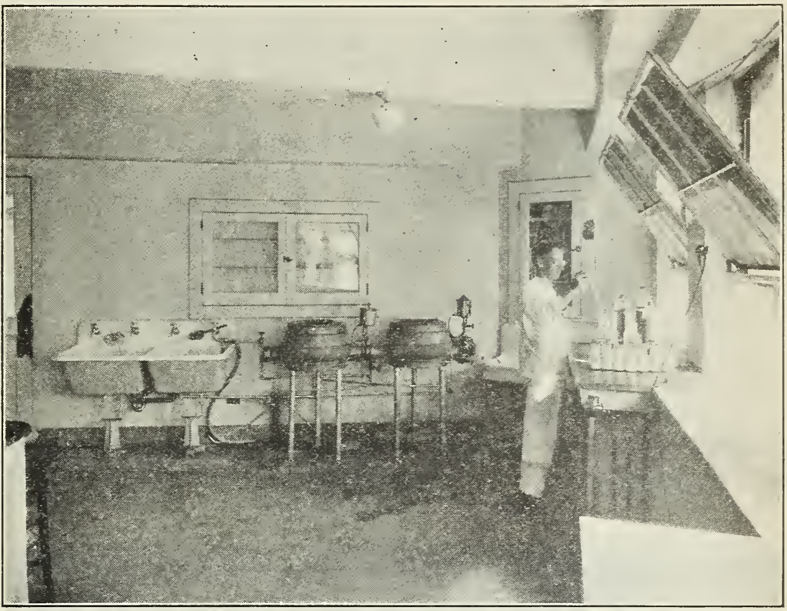

FIGURE 2.—Equipment for making Babcock test

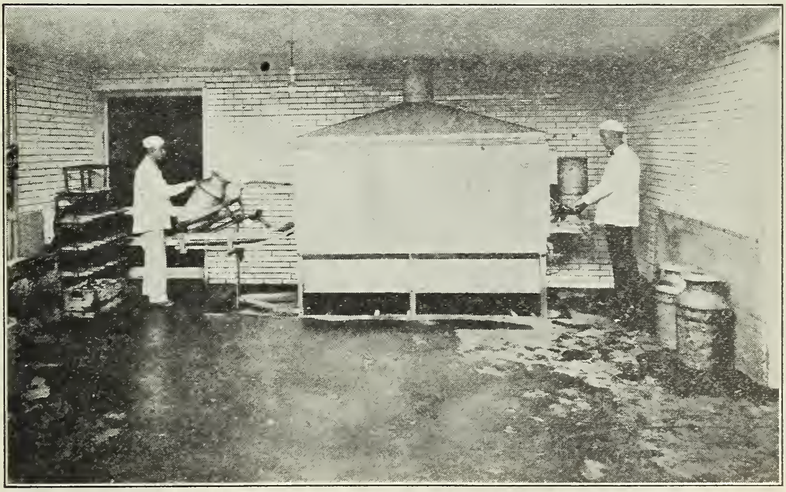

FIGURE 3.—Hydraulic jet can washer (powerful pumps are used with this type of washer, but these are not shown in this illustration)

Many can washers have a device in the first section into which any milk remaining in the can drains and is saved. Where such washers are not in use a separate apparatus for saving the milk should be provided, because a drip saver considerably reduces losses of handling milk at the plant. The apparatus may be homemade or it may be purchased from a dairy-supply house. Collecting pans to catch the drip should be placed under all apparatus where milk is apt to spill and especially under the filling machines. Although the milk saved should not go back to the filler, it may be utilized in other ways. Table 3 shows the quantity of milk saved by drip savers at several plants.

TABLE 3.—*Quantity of milk saved by drip savers at several plants*

Plant No.	Quantity of milk dumped	Quantity of milk saved with drip saver	
	Gallons	*Gallons*	*Per cent*
1	6, 000	16	0. 266
2	4, 000	15	. 375
3	3, 000	12	. 400
4	2, 000	6	. 300

RECEIVING VAT AND STORAGE TANKS OR VATS

From the weigh can the milk is released by a valve and flows by gravity to a receiving vat. Only a small vat is necessary if provision is made for storage tanks and a pump of sufficient capacity to pump the milk to the storage tanks as fast as it comes from the weigh can. At small plants a large receiving vat may be used and the milk pumped from it direct to the pasteurizing department. A larger receiving vat will be required if a continuous system of pas-

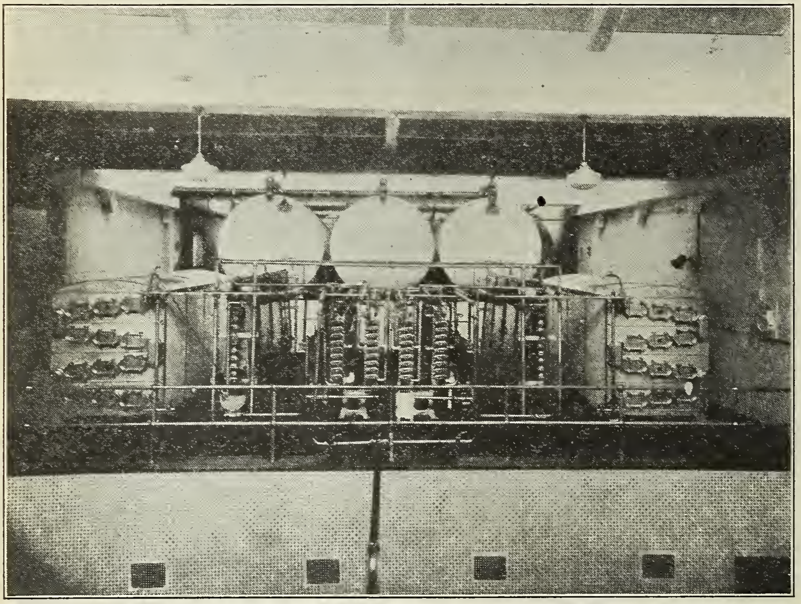

FIGURE 4.—Milk-storage tanks and internal tubular heaters and coolers with long-flow tubular holder

teurization is used than if the vat system of pasteurization is employed, as in the latter case the milk may go direct to the pasteurizing vats, but with the former system some of the milk must be held in the receiving vat so that a uniform flow to the pasteurizer may be maintained. Such a receiving vat may be provided with revolving coils containing a cooling medium. These coils also mix the milk received from various producers.

At large plants the milk generally goes from the receiving vat to large storage tanks or vats either by gravity or by means of a pump. The pump should be large enough to handle the milk as fast as it is received without being forced and should be of sanitary construction. Storage tanks such as those shown in Figure 4 are often used at large plants. These tanks are usually provided with an outside jacket in which a cooling medium can be circulated and the milk held at a low temperature. They are usually lined with enamel or other smooth material so that they can be readily cleaned and sterilized. These tanks may be installed either vertically or horizontally, the latter system being somewhat more desirable from the standpoint of accessibility for cleaning. At many plants milk is held for several hours before it is pasteurized, and in such instances a great saving in cans, refrigeration, labor, and floor space is effected by the use of these storage tanks.

CLARIFIER OR FILTER

The clarifier is used to remove from the milk dirt or other foreign matter. This is retained in the machine as the milk passes through it.

TABLE 4.—*Number of plants of various sizes clarifying milk at specified locations and temperatures*

Number of gallons of milk handled daily	Total number of plants	Plants in which clarifying was done—							
		Between receiving tanks and pasteurizer, with no preheating			Between preheater and pasteurizer [1]			Between heater and holder, at pasteurizing temperature	Between pasteurizer and cooler, at pasteurizing temperature, with no precooling
		Number of plants	Temperature (° F.)		Number of plants	Temperature (° F.)			
			Average	Range		Average	Range		
500 or less	8	5	57.6	50–63	3	90.0	85–95	0	0
501 to 1,000	7	5	57.0	55–60	2	97.5	95–100	0	0
1,001 to 2,000	5	2	60.0	55–65	2	85.0	85	0	1
2,001 to 3,000	9	2	55.0	55	6	88.0	75–95	1	0
3,001 to 5,000	12	5	62.8	39–85	6	83.8	70–95	0	1
5,001 to 10,000	9	3	65.0	35–95	6	105.0	90–115	0	0
10,001 to 20,000	5	4	47.3	40–50	1	90.0	90	0	0
Over 20,000	1				1	70.0	70	0	0
Total or average	56	26	57.8	35–95	27	91.0	70–115	1	2

[1] In some cases no extra equipment for preheating was used, as a section of the pasteurizer was "by-passed" for this purpose.

Table 4 shows the number of plants of various sizes clarifying milk at specified locations. The temperatures of clarification are also shown. It will be noted that most of the plants either clarified the milk cold as it came from the producers or from the storage tanks, or used a preheater, in which case the milk was clarified at temperatures usually between 80° and 90° F. Clarifying cold milk tends to produce more foam than when a preheater is used. High temperatures, however, have a tendency to injure the cream line. Recent improvements in the machines permit the use of the low temperature without the formation of much foam.

At only one plant was the clarifier placed between the heater and holder and at only two plants was the milk clarified after the pasteurization process was completed. The latter is not a desirable practice, as the milk should reach the bottles as soon as possible after pasteurization with a minimum of intervening apparatus.

The clarifier should be large enough to handle the milk as fast as it is received. It is much better that the machine be too large than too small, as in the latter case the milk, if properly clarified, can not be sent to the pasteurizers and bottling machines as fast as they can handle it.

The filter (fig. 9) is another apparatus designed to remove the visible dirt from the milk. Various materials are used, but the most common are cotton pads or cloth with a long-fiber nap on both sides.

TABLE 5.—*Number of plants of various sizes filtering milk at specified locations and temperatures*

Number of gallons of milk handled daily	Total number of plants	Plants in which filtering was done—													
		Between receiving tanks and pasteurizer, with no preheating			Between preheater and pasteurizer [1]			Between heater and holder, at temperature of—				Between pasteurizer and cooler			
												With precooling			At pasteurizing temperature, with no precooling
		Number of plants	Temperature (° F.)		Number of plants	Temperature (° F.)						Number of plants	Temperature ° (F.)		
			Average	Range		Average	Range	145° F.	144° F.	143° F.	140° F.		Average	Range	
500 or less	30	6	65.0	55–70	5	98.0	85–125	1	2	1	0	4	107.5	60–130	11
501 to 1,000	18	3	61.0	55–70	5	106.0	90–120	1	0	0	1	1	125.0	125	7
1,001 to 2,000	37	6	56.7	50–60	7	99.0	90–120	6	0	4	1	6	125.0	100–135	7
2,001 to 3,000	30	3	55.0	50–60	13	96.5	70–137	3	0	1	1	2	129.0	125–133	7
3,001 to 5,000	31	9	39.0	38–40	13	102.3	85–130	1	2	3	0	0	------	-------	3
5,001 to 10,000	49	10	39.1	38–40	21	110.1	90–125	4	2	3	3	0	------	-------	6
10,001 to 20,000	28	2	49.0	40–58	9	119.0	106–130	2	7	3	0	0	------	-------	5
Over 20,000	22	0	-----	------	10	115.0	100–125	1	8	2	0	0	------	-------	1
Total	245	39	49.2	38–70	83	106.5	70–137	19	21	17	6	13	120.2	60–135	47

[1] In some cases no extra equipment for preheating is used, as a section of the pasteurizer is "by-passed" for this purpose.

Table 5 shows the number of plants of various sizes filtering milk at the specified locations. The temperatures of filtration are also shown. The most common location was between the preheater and the pasteurizer. Milk can be filtered efficiently by this method, and there is no opportunity to recontaminate the milk by the filter after the milk has been pasteurized. As a general rule less efficient results are obtained by filtering the milk cold than by first heating it. Although milk can be filtered efficiently at the pasteurizing temperature, it is more desirable from a sanitary standpoint to filter it before it has been heated to this temperature, and in no case is it desirable to filter it after pasteurization has been completed.

Many types of filters and clarifiers which do very efficient work are on the market.

MILK PUMPS

One or more milk pumps are necessary in most milk plants. It is very important that they be of proper construction and kept clean. Practically no injury to the cream line seems to be caused by pumping the cold, raw milk or the hot, pasteurized milk. Pumping at intermediate temperatures, however, especially between 60° and 100° F., is to be avoided, as it tends to injure the cream line.

Some of the troubles encountered with milk pumps are due to faulty installation. The centrifugal pump should be used only when the milk flows directly to the pump. It lifts the milk several feet and works satisfactorily in pumping the milk over the cooler, provided the pump is so placed that the milk flows to it. Other common types are the piston and the rotary pumps, the latter being adaptable where suction is required. A properly operating piston pump agitates the milk very little and should give good results.

PASTEURIZING AND COOLING EQUIPMENT

For pasteurization[2] and subsequent cooling, heaters, holders, and coolers are required. There are many types of these on the market. In the flash system of pasteurization (heating to a high temperature for a short period of time) only a heater and cooler are required. With the holding system the same apparatus may serve the purpose of both heater and holder, though with most systems separate units are required for each.

TABLE 6.—*Number of plants of various sizes using specified systems of heating milk*

Number of gallons of milk handled daily	Number of plants	Plants using batch heaters			Plants using continuous-flow heaters					Plants using vat in combination with preheater
		Spray vat	Vat	Tank	Danish or kettle	Barrel	Internal tubular	Open tube	Film or drum	
500 or less	33	5	19	[1] 5	0	3	1	0	0	0
501 to 1,000	34	3	21	3	1	3	3	0	0	0
1,001 to 2,000	44	2	15	3	2	9	12	0	0	1
2,001 to 3,000	36	1	12	4	0	6	11	0	1	1
3,001 to 5,000	44	1	6	0	3	18	15	0	1	0
5,001 to 10,000	57	2	11	0	4	19	19	0	0	2
10,001 to 20,000	29	0	3	1	1	10	12	1	[2] 1	0
Over 20,000	22	0	0	0	5	12	4	0	[2] 1	0
Total	299	14	87	16	16	80	77	1	4	4

[1] 1 starter can.

[2] Electropure system.

HEATERS

The kinds of heaters most generally used are batch heaters and continuous-flow heaters. Table 6 shows the number of plants of various sizes using the specified systems of heating milk. It will be noted that batch heaters are more common at the smaller plants and that the continuous-flow heaters are more common at the larger plants. The latter statement is especially true of the barrel and internal-tubular types.

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[2] AYERS, S. H. THE PRESENT STATUS OF THE PASTEURIZATION OF MILK. U. S. Dept. Agr. Bul. 342, 16 p., illus. 1916. (Revised, 1926.)

BATCH HEATERS

Batch heaters are of the following types: Rectangular-shaped vat (fig. 5), in which a coil containing the heating medium is revolved, thus heating the milk and keeping it agitated so that the cream does not rise; vat similar to the above, except that the coil is hung vertically instead of horizontally and the vat is more nearly square than rectangular in shape; special-metal or glass-lined tank in which the milk is heated by the introduction of the heating medium in a jacket surrounding the tank, the milk in the tank being gently agitated by a revolving paddle; spray vat, similar to rectangular-shaped vat, except that it is narrower and no coil is required, as the milk is heated by forcing hot water in sprays around the outer surface of the tank. The tank containing the milk is inclosed by another tank, thus forming a jacket. The hot water, after being sprayed against the outer surface of the inner tank, flows to the bottom of the outside tank, whence it is pumped up again through pipes, being heated meanwhile to the desired temperature. Blades or paddles attached to a mechanism on the top frame of the vat keep the milk agitated during the process.

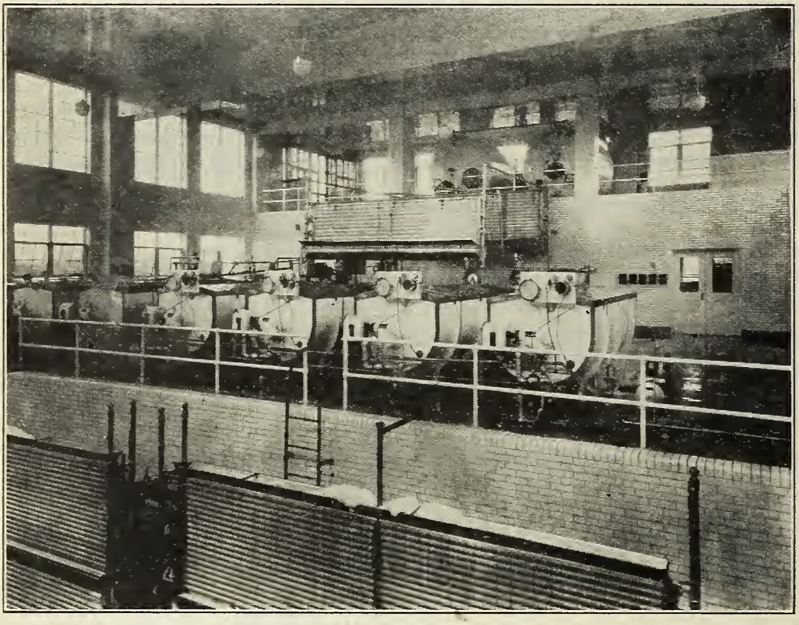

FIGURE 5.—A vat pasteurizing outfit, showing storage tanks, preheater, pasteurizing vats, and tubular coolers

Batch heaters are simple in construction and easily operated. For small plants vats or tanks are economical on account of their many uses. Besides serving as heaters they are used as holders and may also be used in place of receiving and storage tanks. The milk when received may be dumped into the vats and held at the desired temperature until ready for pasteurization. At small wholesale plants the milk, after being heated and held, is sometimes cooled in the vats and stored in them at a low temperature until it is drawn into cans ready to be sent out on the delivery routes. If the batch heaters and holders are properly operated all the milk will be held at the pasteurization temperature for the required length of time, although some of it will be held slightly longer than 30 minutes. During the holding process the milk comes in contact with no additional surfaces between the heating and cooling processes, so that there is no extra apparatus to keep clean or to recontaminate the milk. Where batch heaters are used the capacity of the plant may be readily increased by adding more units.

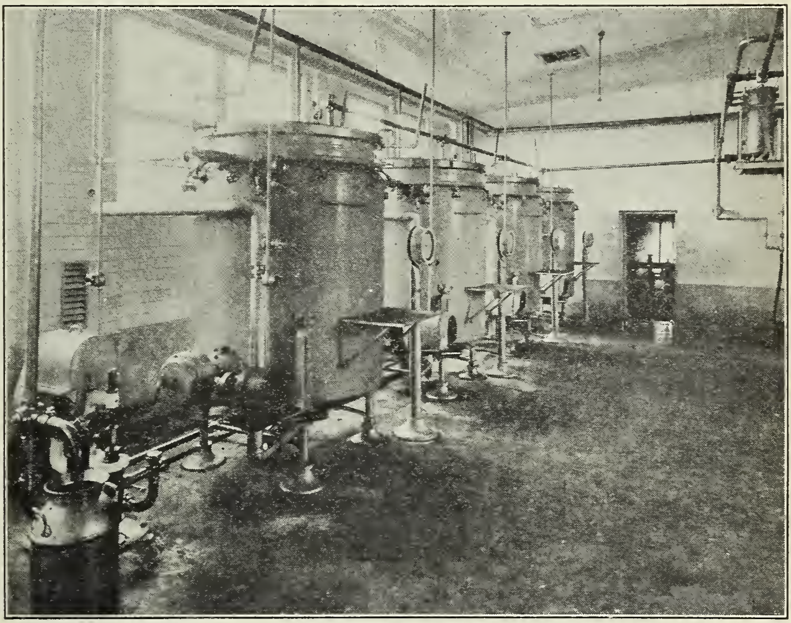

FIGURE 6.—A battery of tank pasteurizers

Although it is possible to cool the milk completely in the vats after pasteurizing by forcing cold water and brine through the coils, this is not a desirable practice when milk is to be put into bottles. It is then desirable to use a separate cooler, as cooling in the vat below a temperature of 100° F.[3] tends to injure the cream line.

A continuous system of pasteurization may be obtained by installing a battery of three or more vats or tanks. (Fig. 6.) While the third vat is being filled and heated the milk in the second is being held and that in the first is being drawn off over the cooler, which should be of ample capacity to cool the milk as fast as it is drawn from the vats. If the milk is cooled to about 110° or 115° F. in the vats before it is allowed to go to the cooler all the milk will be held at the pasteurizing temperature for a uniform length of time and the capacity of the outfit will be increased. Another advantage of precooling is that the recording thermometer will show the exact time the milk has been held at 145° F. The vats should be kept closed to avoid contamination from the air and also evaporation of the milk. It is important that the coils revolve at the proper speed. If they are allowed to revolve too fast injury to the cream line may result.

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[3] WHITTAKER, H. A., ARCHIBALD, R. W., CLEMENT, C. E., and SHERE, L. EFFECT OF VARIOUS FACTORS ON THE CREAMING ABILITY OF MARKET MILK. U. S. Dept. Agr. Bul. 1344, 24 p., illus. 1925.

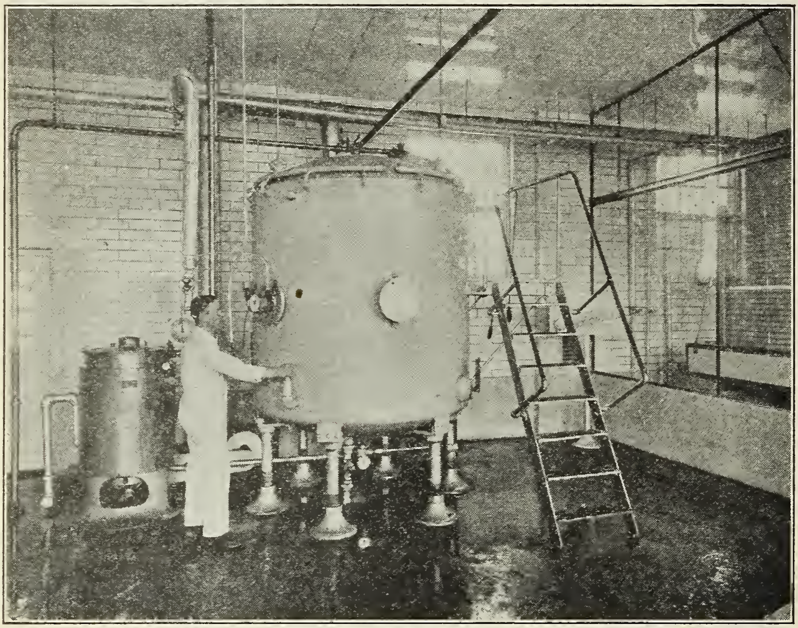

FIGURE 7.—Danish heater with tank holder

At plants where the flow of milk to and from the vats is not automatically controlled the attendant must spend a considerable portion of his time operating the valves. Since it is possible for him to slight the holding time without its being detected by the records, a dependable man for this work is essential.

CONTINUOUS-FLOW HEATERS

In general continuous-flow heaters are of greater capacity for the amount of floor space required than are batch heaters. Continuous-flow heaters are of the following types: Danish or kettle heater (fig. 7), barrel heater, drum or film heater, and internal tubular heater. The Danish or kettle heater consists of a kettlelike chamber surrounded by a jacket. Live steam enters the jacket through small jets. This steam condenses and the jacket is filled with hot water, which heats the milk. The temperature of the water is maintained by the introduction of steam through the jets.

The milk enters the pasteurizer at a point near the bottom and is thrown against the sides of the hot-water jacket by a revolving paddle and forced out through a pipe at the top of the machine. Milk can be elevated several feet with this machine.

The barrel heater (fig. 8) consists of a series of pipes surrounded by a hot-water jacket. The milk is heated by the introduction of live steam into the jacket. The milk enters at the bottom and passes from one end to the other through the various pipes and finally comes out at the top through a pipe. The milk pump is placed in front of the machine and the milk is pumped through the series of pipes or tubes. A thermometer is placed in the outlet pipe of both the Danish and barrel types of heaters.

Very little floor space is required for the Danish and barrel heaters. They may be used with almost any type of holder and are used also where the flash system of pasteurization is practiced. This system of pasteurization is not to be recommended, but the heating units are satisfactory if used with a holding device. These heaters require only a comparatively small investment. Cleaning is not difficult, as the area with which the milk comes in contact is not large. Accurate control of the temperature, however, is rather difficult. The heating surface is so small that the heating medium must be of a considerably higher temperature than that to which the milk is to be heated and steam is introduced directly into the heating chamber. As the temperature of the medium is sometimes allowed to become as high as from 190° to 200° F., portions of the milk may be overheated unless considerable care is exercised. The flow of the milk to the machine, as well as its temperature, will fluctuate somewhat, and unless an accurate automatic temperature control is attached there is almost certain to be an unevenness of temperature in the milk as it comes from the heater, even though a man spends his entire time operating the machine.

It is very important that pumps supplying milk to these heaters should not run too fast and that a uniform quantity of milk should be allowed to flow to the pumps.

Good results are obtained by using a preheater or a regenerator in conjunction with these heaters. In this way the capacity is increased, and the tax on the machine lessened; exteremely high temperatures need not be used. At some plants using this system of pasteurization the milk is heated to from 110° to 120° F. before it enters the pasteurizer proper; thus the milk has to be heated only 25° to 30° more in the machine. Much more satisfactory and uniform results are obtained in this way. Temperatures obtained with preheating systems are shown in Table 10, pages 21 and 22.

A combination of the barrel or Danish heater and a series of vats or tanks will produce good results. The milk can be heated to 120° to 135° F. before it goes to the vats or tanks, and thus the dangers of overheating can be eliminated. The remainder of the heating will be accomplished in the vats or tanks, and the milk will be held in them until it is to be cooled.

In the drum or film heater the milk flows either in a thin film through two or more upright heating surfaces or over a drum inside of which is the heating medium.

With the internal tubular heater (fig. 16) the milk passes through a tube inclosed within another tube. In some of these heaters the outer tube is insulated to prevent loss of heat by radiation. The temperature of the water is maintained by the introduction of steam before it enters the tubes. With the usual types of this machine the hot water enters at one end and is discharged at the other end, traveling in the direction opposite to that in which the milk travels. Thus the temperature of the water when it is discharged from the machine will have been reduced nearly to that of the milk. Furthermore, the milk is heated without any extreme fluctuations of temperature. As the water can be forced through the tubes rather rapidly and the area of the heating surface is comparatively large, the temperature of the water need not be much higher at any time than the temperature to which the milk is to be heated.

In one of the modern internal tubular heaters the machine is divided into sections and the hot water enters and discharges from each section as a unit. With this system it is necessary to heat the water in each section to a temperature only slightly higher than that to which the milk is to be heated, and the water is used more efficiently than in the older types of tubular heaters, as it does not travel over so great an area before it is discharged.

The following are some of the advantages of the internal tubular heater:

Simplicity.
Comparative inexpensiveness of some types.
Adaptability to increase in capacity by adding additional units.
Durability—few moving parts to get out of repair.
Easy utilization of the regenerative principle of heating, which makes for economy of heat and refrigeration.
Easy sterilization, since by closing the ends of the tubes steam can be introduced under pressure and the apparatus thoroughly sterilized.
Extremely high temperatures of the heating medium not necessary.

It is very important that pumps supplying milk to these heaters should not be run too fast and that a uniform quantity of milk should be allowed to flow to the pumps. All machines should have automatic temperature controls.

The pipes or tubes of this type are made to stand pressure, and steam may be introduced into them under pressure for sterilizing. These machines are constructed in small units, so that they can be adapted to plants of various sizes, and the capacity of the heater may be increased at any time by the installation of additional units.

HOLDERS

After the milk has been heated to the pasteurizing temperature it must be held at that temperature for 30 minutes. In order that the holding temperature may be maintained for the required length of time, the apparatus should be insulated or jacketed. The holder is usually separate from the heater. In general there are two types of holders—batch holders and continuous-flow holders.

Table 7 shows the number of plants of various sizes using specified kinds of holders. Although the batch holders were the more common, a large number of the continuous-flow holders of the tubular type were in use. Only two flow-tank holders were in use at the plants surveyed. The use of this type of holder is prohibited by many departments of health because of the lack of accuracy of the holding time.

TABLE 7.—*Number of plants of various sizes using specified kinds of holders*

Number of gallons of milk handled daily	Total number of plants	Plants holding milk in—						
		Batch holders					Continuous-flow holders	
		Vat	Tank	Spray vat	Stationary pocket	Revolving pocket	Tubular	Flow-tank (retarder)
500 or less	35	20	[1] 6	5	2	0	1	1
501 to 1,000	33	21	5	3	1	0	3	0
1,001 to 2,000	42	17	11	3	6	0	5	0
2,001 to 3,000	34	17	7	1	3	0	6	0
3,001 to 5,000	43	9	6	1	19	0	8	0
5,001 to 10,000	59	19	7	2	13	2	15	1
10,001 to 20,000	27	5	7	0	9	1	5	0
Over 20,000	21	3	10	0	5	1	2	0
Total	294	111	59	15	53	4	45	2

[1] 1 starter can.

BATCH HOLDERS

Batch holders may be divided into vat or tank holders and pocket holders. The vats or tanks may also be used as heaters, a description of which is given on pages 10, 11, and 12. The walls are insulated or jacketed so that the pasteurizing temperature is maintained during the holding process. In some cases the valves controlling the flow of milk to and from these vats or tanks are operated by hand, and in other cases the entire operation is automatic. At small plants where only one or two tanks or vats are used the method of operating by hand is rather common.

Pocket holders are either stationary or revolving. One type of stationary pocket holder consists of a series of tanks into which the heated milk flows, and from which it is released after the holding period, the process of letting the milk in and out being automatic. Another type has a series of compartments with valves at the entrance and discharge end of each. (Fig. 8.) These valves are automatically controlled by a revolving mechanism which is operated by a motor. These holders should be checked from time to time to see that the operation of the valves is perfectly controlled, that none of the valves leak, and that the valve at the discharge end of the compartment to be filled is always closed tight before the milk begins to flow in so that none of the milk will pass through without being held.

The revolving pocket holder shown in Figure 9 is divided into six compartments. The milk flows from the heater to one of these compartments. The device revolves slowly, and when the particular compartment reaches a certain point the milk is automatically released through a passage and it then goes to the cooler. As the tank revolves this compartment is again filled. The apparatus is so con-

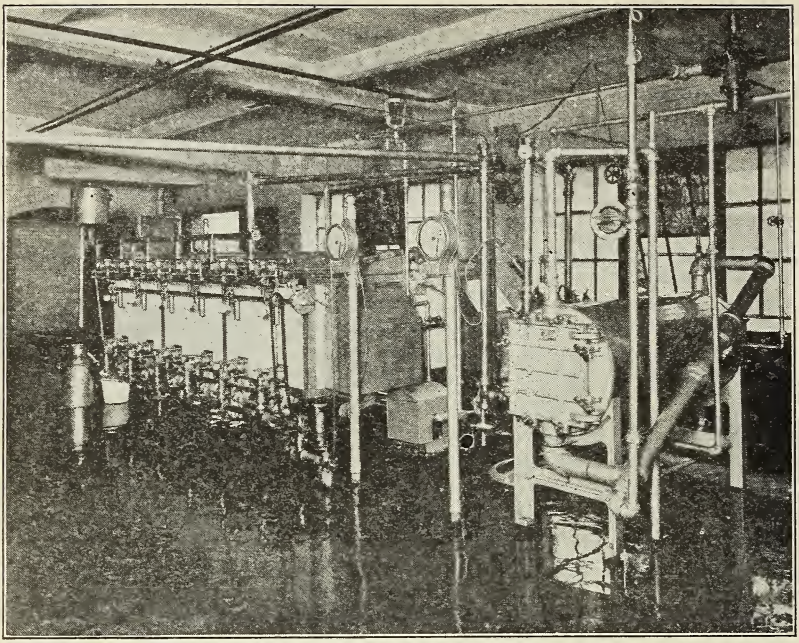

FIGURE 8.—Left, a holder of the compartment type; right, a barrel heater

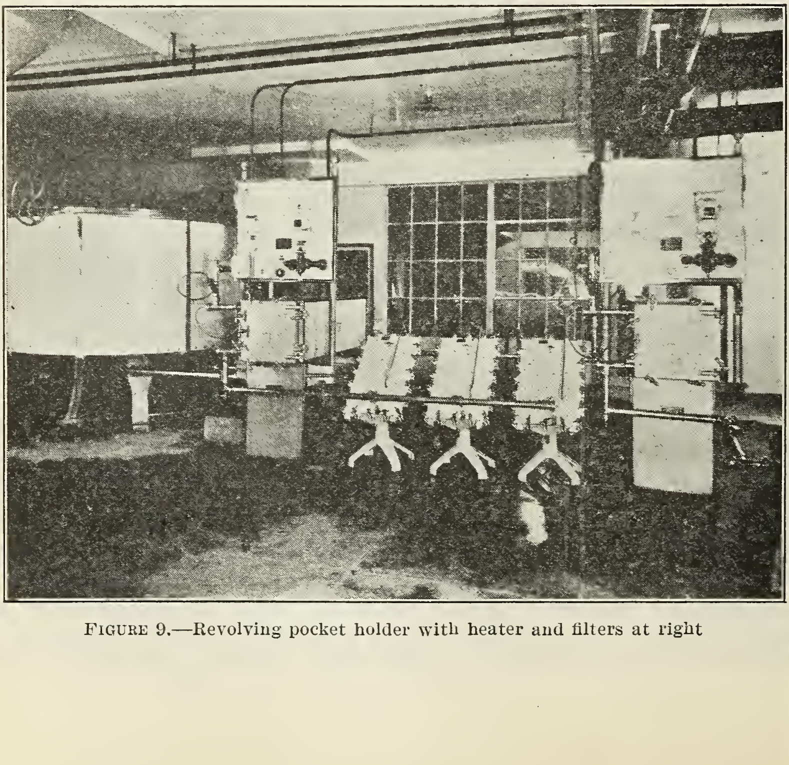

FIGURE 9.—Revolving pocket holder with heater and filters at right

trolled automatically that 30 minutes elapses from the time any compartment is filled before the milk is released to the cooler.

Neither the stationary nor the revolving type of compartment holder, if operated properly, holds the milk much longer than one half hour, as a compartment is emptied in a comparatively short time.

CONTINUOUS-FLOW HOLDERS

In the continuous-flow holders the flow of milk is retarded by some obstruction, such as baffle plates or turns in the apparatus. One type of holder consists of a series of tanks. The milk flows from one tank as soon as it is full to the next tank. It is supposed to take 30 minutes for the milk to flow from the entrance of the first tank to the discharge end of the last tank, but tests have shown that the holding time is not always uniform.

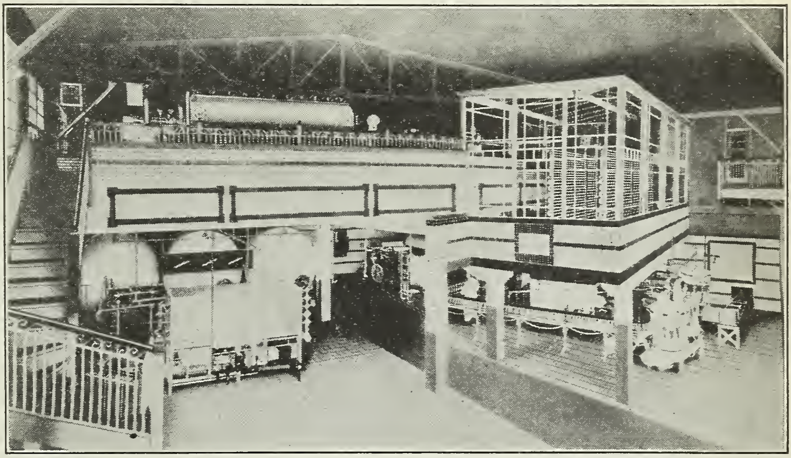

FIGURE 10.—Milk-handling room of a modern milk plant, showing storage tanks and heater at left and revolving continuous-flow holder on the mezzanine floor

Another type of continuous holder consists of a series of long tubes through which the milk passes from the heater to the cooler. Tests have indicated that this holder is accurate as long as the pump is operated at the specified speed. (Figs. 4 and 16.)

In still another type (Fig. 10) the milk enters at one end of the apparatus, which slowly revolves and gradually forces the milk to the other end, where it is discharged to the cooler. The revolution of this apparatus is automatically controlled and it can not be made to revolve above the specified speed. This holder has only recently been developed, but very satisfactory results are reported from those in use.

Good results have been obtained with many continuous-flow holders. In some types, however, some of the milk may not be held so long as the rest, or all of it may be forced through the apparatus and none be held the proper length of time. Tests should be made on all continuous holders to ascertain whether the milk is being properly held, and only those holders that are accurate should be used.

Several tests are quite reliable, among them the color test and the temperature test. With the color test the holder is filled with water and the apparatus set in operation in the usual way. A solution of a substance of a distinctive color is introduced at the entrance of the holder and the time that the color first appears at the outlet of the holder is observed by the operator. Methylene blue and uranin have been used for the operation of the color test. With the temperature test the temperature of the water as it enters the holder is suddenly raised or lowered several degrees and the time at which the temperature of the water at the outlet of the holder changes is noted. Certain kinds of bacteria which produce a distinctive color have also been used for testing the accuracy of the holding time of continuous-flow holders.

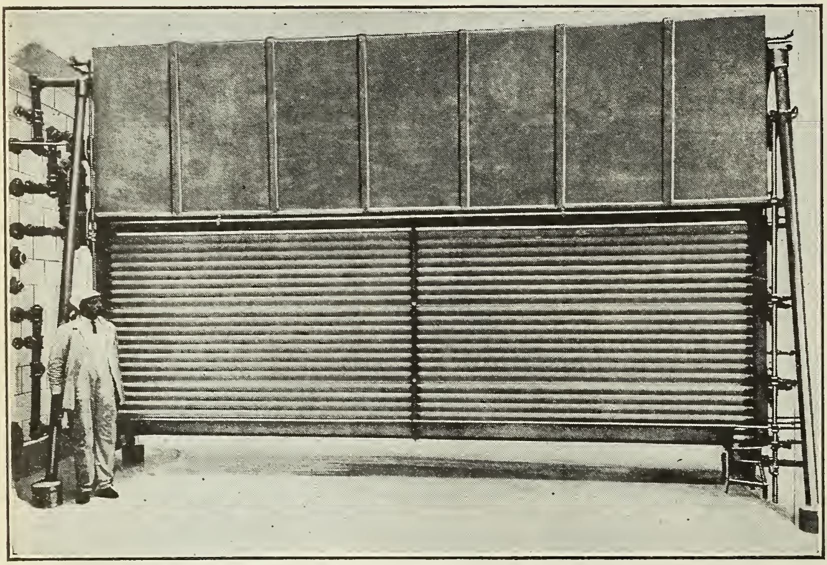

FIGURE 11.—Open-surface milk cooler

COOLERS

Two types of coolers are in common use—the open-surface tubular cooler (figs. 5 and 11) and the internal-tubular cooler. (Figs. 4 and 16.) With the open-surface cooler the milk passes over the tubes in a thin film and the cooling medium passes through these tubes. This cooler is so constructed that water can be used in the top sections and brine or direct-expansion ammonia in the bottom sections. Where the regenerative system of pasteurization[4] is used the cold, raw milk is often allowed to pass through the inside of the first sections of the cooler.

With the open-surface cooler the milk is exposed to the air in the room, and for that reason the air should be kept pure. If the cooler is covered contamination from the air will be reduced. It is more desirable, however, to have pure air in the room where the cooler is located, as considerable care is required to keep the covers clean and they are often clumsy to handle. If covers are used the sterilization of the cooler is made easier.

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[4] See pp. 21 and 22.

The internal-tubular coolers are constructed on the same principle as the internal-tubular heaters; that is, the milk passes through a pipe which is itself inclosed in a pipe or jacket containing the cooling medium. The number of cooling coils required is about double that of heating coils. With this type of cooler the milk does not come into contact with the air at any time. There is no loss of milk from evaporation, therefore, whereas there may be some loss from this source with the open cooler, especially if it is in a draft.

It is easier to sterilize the internal-tubular cooler than the open-surface cooler. If steam is introduced into the former and the apparatus closed it can be thoroughly sterilized. One way to sterilize the surface cooler is to admit steam to the inside of the tubes and at the same time run hot water over the outside of the cooler. The hot water will be vaporized and quite thorough sterilization will result.

Table 8 shows the number of plants of various sizes using the specified kinds of coolers. Tubular coolers were used in the great majority of plants and the open-surface coolers were somewhat more common than the internal-tubular coolers. This is especially true in the case of the smaller plants. At three plants the milk was entirely cooled in vats. This is not a desirable practice because of the danger of injuring the cream line. Three of the plants used a cooler which consists of a conically shaped drum over the outside of which the milk flows in a thin film with the cooling medium on the inside.

The capacity of the milk cooler should be ample to cool the milk as fast as it comes from the holder.

TABLE 8.—*Number of plants of various sizes using specified systems of cooling milk*

Number of gallons of milk handled daily	Total number of plants	Plants cooling milk with—			
		Open-surface tubular cooler	Internal-tubular cooler	Vat cooler	Cone cooler
500 or less	33	28	3	2	0
501 to 1,000	32	25	6	0	1
1,001 to 2,000	45	30	15	0	0
2,001 to 3,000	38	24	14	0	0
3,001 to 5,000	46	26	20	0	0
5,001 to 10,000	59	27	30	1	1
10,001 to 20,000	30	18	11	0	1
Over 20,000	21	12	9	0	0
Total	304	190	108	3	3

In practically all milk coolers the temperature of the hot, pasteurized milk is first reduced by cold water. In the milk regenerative system[5] it is first reduced by the incoming cold, raw milk. To precool by water, coolers are so constructed that water can be used as the cooling medium in the first section. In some cases there are two sections for the circulation of water, permitting its more economical use. In the remaining section either direct-expansion ammonia or brine is used as the refrigerating medium. In the first case the liquified ammonia as it comes from the compressor is expanded directly into the cooling coils and the change to the gaseous state absorbs the heat from the milk flowing over the outside of the cooler. A special type of steel tube must be used in direct-expansion coolers. In the brine system the brine, which usually consists of a solution of calcium chloride or of common salt, is pumped from a tank through the cooling coils. As this solution has a low freezing point, a low temperature can be maintained without danger of freezing the solution. The temperature of the brine is maintained by expanding the ammonia into coils which are placed in the brine tank or in a separate brine cooler. Table 9 shows the number of plants of various sizes using the specified systems of cooling milk.

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[5] See pp. 21 and 22.

TABLE 9.—*Number of plants of various sizes using specified systems of cooling milk*[1]

Number of gallons of milk handled daily	Total number of plants	Plants cooling milk with—			
		Brine	Direct expansion	Both brine and direct expansion	Ice water
500 or less	34	30	3	0	1
501 to 1,000	31	24	6	0	1
1,001 to 2,000	41	31	7	3	0
2,001 to 3,000	35	27	6	2	0
3,001 to 5,000	47	35	10	1	1
5,001 to 10,000	60	50	10	0	0
10,001 to 20,000	32	23	9	0	0
Over 20,000	21	14	6	1	0
Total	301	234	57	7	3

[1] In all cases water was used as the cooling medium in the first section.

Brine was by far the most common cooling medium, 234 plants out of a total of 301 using this method of cooling. Only 57 plants used the direct-expansion method. Among the advantages of the use of brine over the use of the direct-expansion system alone are the following: (1) Its greater elasticity—the brine can be stored for cooling after the refrigerating machine has been shut down or in case of a breakdown; (2) the fact that there is less danger of freezing the milk on the cooling pipes; and (3) the fact that special tubes are not required and there is less danger of leakage.

The direct-expansion system has the advantages of (1) greater economy at plants where it is necessary to run the machine continuously, as less refrigeration will be lost if the ammonia goes directly to the cooler than if it goes through the secondary brine medium; (2) simpler operation; and (3) smaller initial expenditure required for equipment.

At some plants direct-expansion coils are used in the milk-storage room, and brine is circulated from a tank, usually in the storage room, through the milk cooler. Whether direct expansion or brine is used in cooling the milk, it is always desirable to use water in the first few coils of the cooler, as refrigeration is thus saved. In some plants, instead of using brine or direct expansion for cooling the milk, water cooled by means of brine coils or direct expansion coils is used. In this way the temperature of the cooling medium is accurately regulated, and extreme temperatures are avoided.

REGENERATIVE PRINCIPLE IN PASTEURIZATION

By applying the so-called regenerative principle of pasteurization many plants are able to cut down the amount of heat and refrigeration required. This principle may be applied when either milk or water is used as the heating or cooling medium. With one type of milk-regenerative system the cold, raw milk before going to the pasteurizer passes through the first section of the cooling tubes over which the hot milk from the holder flows. With the other type the cold, raw milk passes over the outside of the tubes and the hot pasteurized milk coming from the holder passes through the tubes. With these milk regenerative systems the incoming milk is often heated to between 110° and 120° F. before it goes to the heater proper, while the hot, pasteurized milk is precooled by the incoming milk often to 60° to 70° before it reaches the tube containing the cooling water.

With the water-regenerative system the water from the first section of the cooler, having been heated to within a few degrees of the hot milk which passes over the tubes through which the water flows, needs to have only a few heat units added to it before it goes to the preheater to heat the incoming milk. The water from the heater, having been cooled by the incoming milk, goes to the cooler, where it is used for precooling the hot milk.

Table 10 and Figure 12 show the results of a study made at 51 plants using the milk-regenerative system and 17 plants using the water-regenerative system. Although both systems effect economies in the use of steam and refrigeration, the milk-regenerative system is slightly more efficient, since the hot milk from the holder directly heats the incoming cold milk, and vice versa. On an average, the milk was preheated 70.5° F. with the milk-regenerative system and 53.8° with the water-regenerative system, and was precooled 65.6° with the milk-regenerative system and 57.8° with the water-regenerative system. From a sanitary standpoint, however, the milk-regenerative system is somewhat less desirable because the inside of the pipes through which the incoming raw milk passes must be cleaned after each run.

TABLE 10.—*Temperatures of milk at pasteurizing plants using milk or water regeneration*

System of regeneration	Total number of plants	Temperature of milk as received (°F.)		Temperature of milk after being preheated by regeneration (°F.)		Degrees of heat added to milk by regeneration (°F.)		Temperature of milk coming from pasteurizer (°F.)	
		Average	Range	Average	Range	Average	Range	Average	Range
Milk	51	42.6	33–55	113.1	70–130	70.5	25–90	143.4	140–145
Water	17	47.7	38–60	101.5	75–120	53.8	35–81	143.2	142–145

TABLE 10.—*Temperatures of milk at pasturizing plants using milk or water regeneration*—Continued

System of regeneration	Total number of plants	Degrees of heat added to milk by steam or hot water (°F.)		Temperature of milk after being precooled by regeneration (°F.)		Degrees of heat taken from milk by regeneration (°F.)		Final temperature of milk (°F.)		Degrees of heat taken from milk by refrigeration (°F.)	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Milk	51	30.1	13–73	77.5	50–120	65.6	23–93	39.8	35–50	37.4	13–70
Water	17	41.8	24–68	85.5	50–120	57.8	23–105	39.1	35–45	46.4	10–108

At many plants the milk is preheated by regeneration to from 85° to 90° F. before it goes to the clarifier or filter. At these temperatures the clarification or filtration is more efficient, and less foam is produced than if the operation is performed when the milk is cold. Preheating also helps to render the pasteurization of the milk more uniform, as the milk goes to the machine at a fairly constant temperature.

Table 4 shows that at 27 of the 56 plants using clarifiers the milk was preheated before it went to the clarifier, and Table 5 shows that at 83 of the 245 plants using filters the milk was preheated before it went to the filter. In many cases regeneration is used for the preheating process.

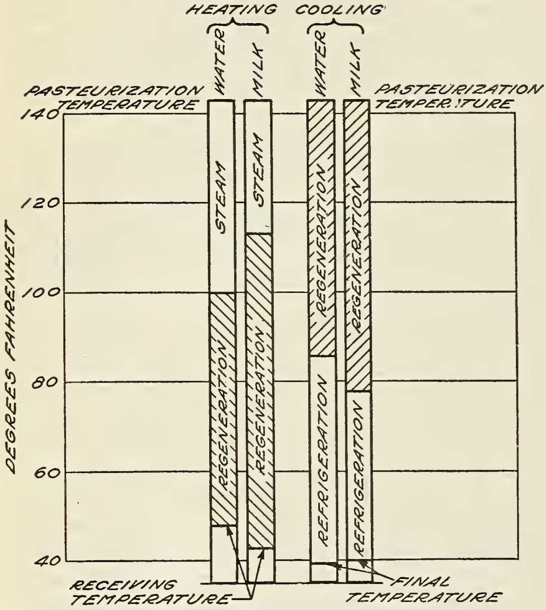

FIGURE 12.—Comparison of efficiency of milk and water regenerative systems in heating and cooling milk (17 plants, water-regenerative system; 51 plants, milk-regenerative system)

OTHER SYSTEMS OF PASTEURIZATION

IN-THE-BOTTLE PASTEURIZERS

With the in-the-bottle system of pasteurization the milk is pasteurized and cooled after it has been put into the bottles. In some pasteurizers the bottles of milk in the cases are heated, held, and cooled in the same apparatus or compartment. In others the bottles of milk, after being removed from the cases, pass slowly through the machine, being heated at the beginning and cooled at the end of the process. It takes 30 minutes for the bottles of milk to pass from the point where they have been heated to the pasteurizing temperature to the point where cooling is begun. The milk usually is heated by passing sprays of hot water over the bottles. Either a special cap is used or the bottles are covered with a specially constructed pan. In the latter case the hot water flows through small holes in the pan and passes over the bottles in the form of a film. The milk is cooled by changing from hot water to cold. With some types of in-the-bottle pasteurizers, after the milk has been heated, held, and cooled it remains in the machines and is kept at a low temperature until time for delivery. With one type, the milk in the bottles is heated by live steam and cooled by immersing the bottles in cold water. With still another type the bottles of milk are heated by being immersed in vats containing hot water.

The chief advantages of this system of pasteurization are as follows: (1) It has no apparatus, pumps, and pipes to be cleaned; and (2) there is little chance of the milk being recontaminated after pasteurization, provided water-tight caps are used and the bottles do not have to be recapped, as the milk does not come in contact with any other apparatus after pasteurization. The chief disadvantages of this system are as follows: (1) It is rather slow for a large plant; (2) it requires considerable floor space; (3) the cost of operation is greater than with the other systems of pasteurization, since extra heat and refrigeration are required to heat and cool the bottles and caps and, with some types, the cases also; and (4) either a more expensive cap must be used or many of the bottles may have to be recapped, in which case the milk may be recontaminated. Because of these disadvantages, this system is not used to any great extent.

PASTEURIZATLON BY ELECTRICITY

A system of pasteurizing milk by electricity has been developed in recent years. Usually with this system the milk is cooled at once, without the usual 30-minute holding period. Anyone contemplating its use should take into consideration the following factors: (1) Whether or not this method of pasteurization without holding will receive the approval of the local health authorities and (2) the cost of operation as compared with that in other systems. This cost will depend largely on the rate at which electricity can be obtained from the electric-power companies and will vary greatly in different localities. The equipment required for this system is very simple and can easily be cleaned. Furthermore, comparatively little floor space is required.

PASTEURIZING MILK IN CAN

At very small plants milk is sometimes pasteurized in the can by immersing the can of milk in a tank containing hot wter. Apparatus for this purpose can also be obtained from some dairy-supply houses.

MISCELLANEOUS EQUIPMENT

TEMPERATURE REGULATOR

It is essential that the temperature of pasteurization be accurately controlled, not only to procure efficient pasteurization but also to avoid injuring the cream line and the chemical properties of the milk. An accurate automatic device for controlling temperatures should be installed on all pasteurizing outfits.

RECORDING AND INDICATING THERMOMETERS

All pasteurizing outfits should also be supplied with thermometers which will record the temperature to which the milk has been heated. These instruments will also record the time required to heat the milk, and in some cases they can be so installed as to show the time the milk has been held at the pasteurizing temperature. From the records made by these instruments the plant superintendent is enabled to keep a reliable check on the operator of the pasteurizer.

In addition to recording thermometers, pasteurizing outfits should also be equipped with indicating thermometers. The divisions on the scale of such thermometers should be large, so that the temperature that is registered can be readily observed by the operator.

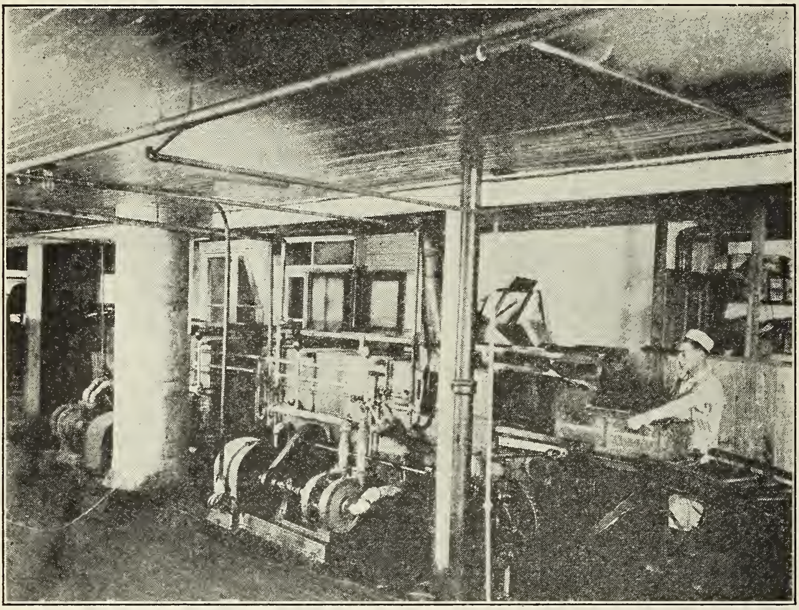

FIGURE 13.—Bottle washer of the pressure type in which the bottles are washed in the case

SPECIAL KINDS OF VALVES

It is important that the heater or holder have no pockets or dead ends in which the milk is not subjected to the heating process or to sufficient agitation to keep the temperature up to the required point during the holding period.

Flush-type valves should be installed on all pasteurizing apparatus where there is any likelihood of such trouble. Leak-detector valves should be used in inlets and outlets of pasteurizing vats or other apparatus where a leak in the valve might result in some of the milk passing through the apparatus without being heated or held the required length of time. With the use of these leak-detector valves if any milk does leak it will drop on the floor.

BOTTLE WASHERS

In general there are three types of bottle washers—the small brush washer, the hydraulic-pressure in-the-case bottle washer, and the soaker type of washer.

The small brush washer consists of (1) a tank, which is filled with the washing solution in which the bottles are allowed to soak; (2) a brush, which is made to revolve by steam turbine, motor, or belt power and onto which the bottle is forced by the operator (in some cases three brushes in a row are used so that the bottle is brushed on the outside as well as on the inside); (3) a chamber in which a case of bottles, after being brushed, is inverted for the purpose of rinsing with hot water and steam. With some machines this is accomplished by means of a 2-way valve through which first hot water and then live steam are forced into the bottles. Other machines are provided with a pump which forces hot water into the bottles. This type of washer is suitable only for small plants and is not in very general use.

The hydraulic-pressure in-the-case bottle washer (fig. 13) consists of a series of tanks containing washing-powder solutions and rinsing waters. These waters are forced through small jets into the bottles by powerful pumps. Usually the first tank contains a lukewarm rinsing water, the second tank the washing solution, and the other tanks hot rinsing waters. The temperature of the last water is at or near the boiling point, and in some cases the bottles receive a spray of steam. One man usually feeds the cases of bottles into the machine and another man takes them out at the other end and piles them in stacks so they will cool. Junk bottles or other very dirty bottles are sometimes not readily cleaned by these machines. Such bottles should be soaked in a strong washing solution and washed first with a brush machine and then sent through the pressure washer for rinsing and steaming.

Temperatures of the solutions in the tanks of hydraulic-pressure washers at four plants are shown in Table 11.

TABLE 11.—*Temperatures of solutions and waters in tanks of hydraulic-pressure washers observed at four plants*

Plant No.	Temperature (°F.) of solution in—			
	Tank 1	Tank 2	Tank 3	Tank 4
1	90	120	160	200
2	100	120	140	170
3	110	150	180	----------
4	90	140	180	----------

It is very important that the proper temperature is maintained in each tank. The temperature of the solution in the first tank must not be so high as to break the bottles, and it should be increased in each tank so that the final one will be kept at a temperature near the boiling point. Care must also be taken to have the proper solutions in each tank. In large machines the first tank contains a strong alkali solution, the second a milder solution, and the remaining tanks rinsing water.

In the soaker type of bottle washer (fig. 14) the bottles are removed from the cases and fed into the machine, where they are prerinsed and then soaked or sprayed with two or more solutions containing strong alkali, which acts both as a cleaning and as a sterilizing agent. The temperature of the various solutions is gradually increased.

After this process the bottles are brushed on the outside. In some types they are brushed on the inside also. Where no brushes are used on the inside of the bottles the bottles are subjected to sprays of hot water under high pressure. With one type air is mixed with these sprays, thus forming an " air brush."

Rinsing waters are then forced into the bottles. The temperatures of these waters are gradually reduced, and when the bottles come from the final water they are cool enough to be filled immediately. In some cases a sterilizing agent is used in the final rinsing water.

After the bottles come from the machines (fig. 15) they are transferred by conveyors directly to the fillers. The cases, when empty, are placed on a conveyor which carries them through a case washer and thence to the fillers. Considerable economies in labor of washing and filling the bottles are effected with this system, as no handling of the bottles between the washers and fillers is required.

Table 12 shows the number of plants of various sizes using the specified systems of washing bottles. At the time this survey was made (1927) the plants were about equally divided between the soaker type and the in-the-case type of bottle washers. The use of the latter, however, is gradually being discontinued in favor of the former, which requires less labor for washing and filling the bottles. The breakage of bottles is also less, as there is not so much handling of bottles and the temperatures are usually controlled more accurately.

Only a few small plants were using the brush washers.

TABLE 12.—*Number of plants of various sizes using specified systems of washing bottles*

Number of gallons of milk handled daily	Total number of plants	Plants using specified type of bottle washer		
		Soaker type	In-the-case washer	Small brush washer
500 or less	34	2	23	9
501 to 1,000	31	4	25	2
1,001 to 2,000	44	16	28	0
2,001 to 3,000	35	24	11	0
3,001 to 5,000	46	24	22	0
5,001 to 10,000	58	34	24	0
10,001 to 20,000	30	23	7	0
Over 20,000	22	21	1	0
Total	300	148	141	11

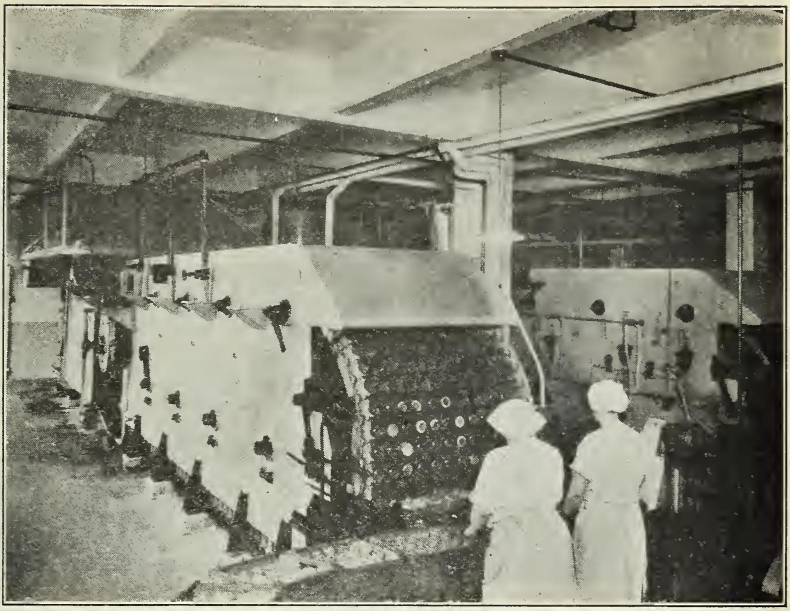

FIGURE 14.—A soaker type bottle washer in use

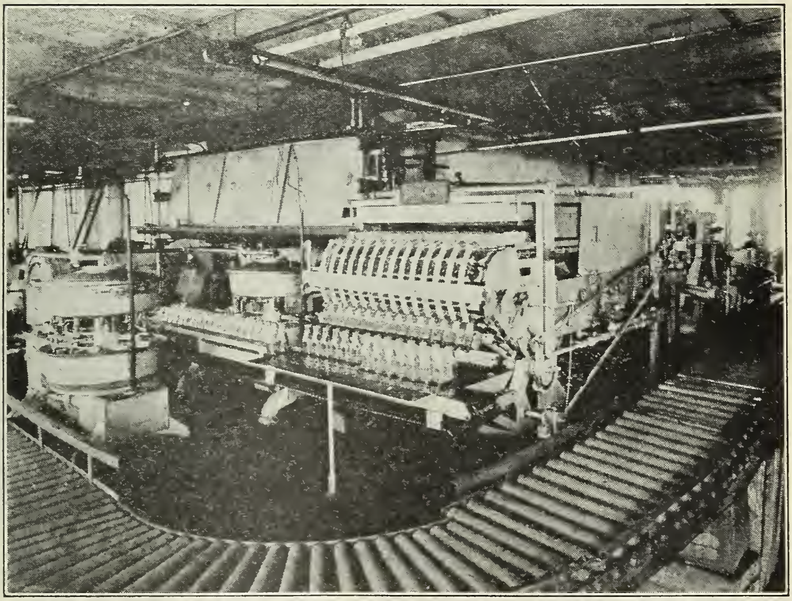

FIGURE 15.—Discharge end of a soaker type bottle washer. The bottles are automatically conveyed to the fillers at the left

FILLERS AND CAPPERS

After the milk has been pasteurized and cooled it is bottled and sealed ready for delivery to the consumer. For this purpose fillers and cappers are required. Formerly fillers which were operated by hand levers were used, and the bottles were capped by hand to a considerable extent. At present, however, at practically all plants automatic fillers and cappers are used. In their operation there is no necessity for the milk or the cap to come in contact with the human hand. The rotary fillers and cappers are the most common. (Fig. 16.) This machine consists of a circular tank with valves similar to those in other types of fillers. Each bottle is automatically raised as it comes under the valve and the milk flows into it. When the bottle has traveled the full revolution of the tank, it is automatically lowered and the valve closes. The bottles are then carried to the capper, which caps them automatically. Tubes extending from the top of the tank to the valve allow the air to escape and prevent foam. Several sizes of these machines are on the market and the tanks have six or more valves. From 24 to 72 bottles may be filled and capped per minute, depending on the size of the machine. In operating the larger machines of this type where the continuous system of washing and filling is not used one man is required to feed the machine and another to take the filled bottles away. Only one man is required to operate the smaller machines. Large plants have a battery of three or more of these machines. (Fig. 17.)

Table 13 shows the number of plants of various sizes using specified systems of filling and capping bottles. It will be noted that at practically all plants the rotary type of filler is used.

LABOR-SAVING DEVICES

Considerable labor can often be saved by the use of devices such as elevators and conveyors. Some conveyors operate by gravity, others by power. Although such equipment is expensive, conveyors to bring the milk from the receiving platform to the dump tank will save considerable handling, as will also conveyors to bring the bottles from the checking-in platform to the washers and to convey the filled bottles from the filling room to the milk-storage room and out to the delivery wagons.

TABLE 13.—*Number of plants of various sizes using specified systems of filling and capping bottles*

Number of gallons of milk handled daily	Number of plants	Plants using specified type of bottle filler		
		Rotary system	Case system	Single-row system
500 or less	31	31	0	0
501 to 1,000	31	31	0	0
1,001 to 2,000	45	44	0	1
2,001 to 3,000	35	35	0	0
3,001 to 5,000	51	49	1	1
5,001 to 10,000	60	59	0	1
10,001 to 20,000	30	29	0	1
20,001 and over	22	21	0	1
Total	305	299	1	5

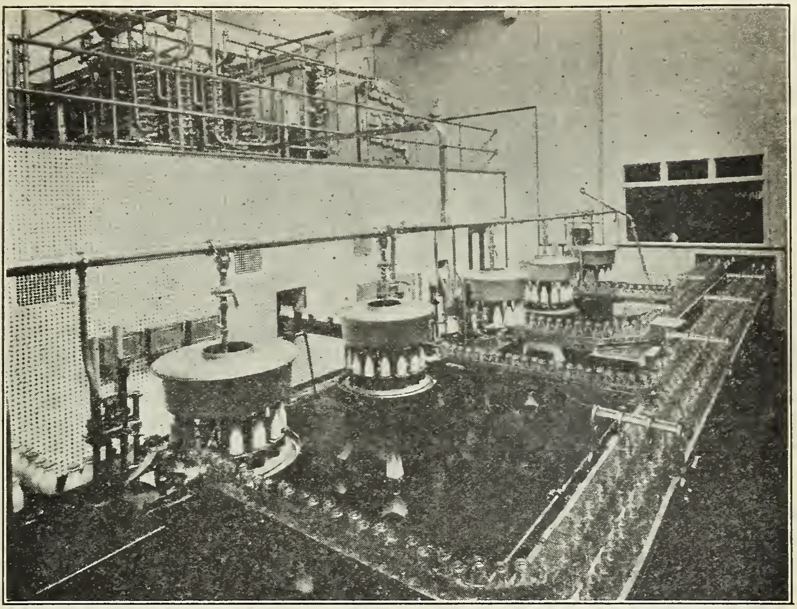

FIGURE 16.—View in bottling room showing rotary fillers and pasteurizer of internal-tubular type

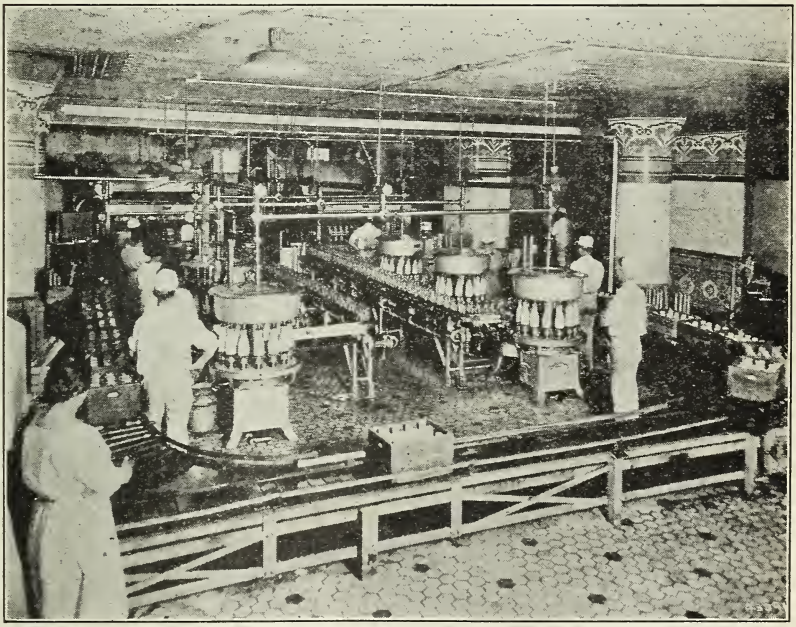

FIGURE 17.—A battery of bottle fillers of the rotary type. Bottles are moved automatically to the fillers on conveyors from the discharge end of the soaker-type bottle washers

POWER PLANT

The power plant should be entirely separate from the milk department and is often in another building. It is important that the boiler room be far enough away and so inclosed that dirt, soot, or gases can not reach the milk-handling rooms. The power plant should be of ample capacity for all anticipated requirements. It may be advisable for large plants to have an extra boiler and an extra refrigerating machine. Power may be saved at certain times of the year by operating only one of the machines when the full capacity of refrigeration is not needed. Having two boilers makes it possible to clean or repair one of them without shutting down the plant.

STEAM OR ELECTRIC POWER

Whether a steam engine or electric motors should be used will depend largely upon the costs of current and coal. The use of motors has several advantages, and direct-connected motors for each machine are advisable wherever possible, although where several machines are grouped together less power will be required if only one motor is used to run the shafting for all the machines. At large plants electric current to run the motors can often be generated for less than it can be bought. Some of the advantages of direct-connected motors are:

Simplicity of operation.
Cleanliness.
Use of power only when machine is operated.
Small space required.
Accuracy with which amount of power used in operating a machine may be determined.
Elimination of insanitary hangers, shafting, and pulleys.

The following are some of the advantages of the use of steam engines in milk plants:

The source of power is under the control of the milk plant.
An additional steam boiler need not be purchased, since one must be used to supply steam for hot water, pasteurizing, sterilizing, and for heating the building.
The exhaust steam can be utilized for heating water to be used in the plant.

Whatever power is used it is well to have an auxiliary system, so that if anything happens to one system the plant will not have to be shut down. A plant using electric power should have an engine or extra motors for an emergency, and for the same reason a plant using steam power should install electric motors.

MECHANICAL REFRIGERATION

Most large plants use mechanical refrigeration, but many smaller ones still depend upon ice. Individual conditions will determine which will be more economical to use.

Under ordinary circumstances mechanical refrigeration is cheaper than the use of ice for large plants. With careful operation there is very little waste of refrigeration, the original cost of machinery and the labor and power being the chief items of expense. In small plants, however, it is often a problem to the dealer whether to install a mechanical refrigerating plant or to depend upon ice.

In deciding this question it is necessary to consider such factors as the price of ice, quantity required each day, labor of handling, the disadvantages incident to its use, and the certainty of a supply. Then come the questions of size, initial cost, and the cost of operation of a refrigerating plant which would accomplish the same result.

In some cases it may be necessary to increase the size of the boiler and of the engine, which should be large enough to run the compressor (fig. 18) while the pasteurizer, bottle washer, and other machinery are being operated. If electric power is to be used the size of the boiler need not be considered.

In comparing the cost of mechanical refrigeration with that of ice it should be remembered that in many cases the former is of greater value than can be estimated on account of the better results obtained, for when ice is used it is often difficult to maintain a temperature low enough to keep the milk in proper condition.

Aside from the possibility of accident, a refrigerating machine can be depended upon to supply the requisite amount of refrigeration at all times. Furthermore, it results in cool, dry air in the storage room, produces lower temperatures than ice, and permits more accurate control of temperature. Where mechanical refrigeration is used less ice is required on the delivery wagons, since the original temperature of the milk is lower.

At some plants the liquid ammonia from the compressor is expanded directly into pipes in the milk-storage room, while at other plants the ammonia pipes are placed in a brine tank or in a special brine cooler, and this brine, which has been cooled by the ammonia expanded in the pipes, is pumped through pipes in the milk-storage room.

Table 14 shows the systems of refrigeration used in the milk-storage room at 299 plants.

TABLE 14.—*Number of plants of various sizes using specified systems of refrigeration in milk-storage room*

Number of gallons of milk handled daily	Total number of plants	Plants using specified type of refrigeration			
		Direct expansion and brine combined	Direct expansion	Brine	Indirect (fanned in from outside bunker)
500 or less	33	7	11	15	0
501 to 1,000	30	11	8	11	0
1,001 to 2,000	43	8	20	15	0
2,001 to 3,000	35	11	11	13	0
3,001 to 5,000	47	6	23	18	0
5,001 to 10,000	60	6	14	38	2
10,001 to 20,000	30	6	7	15	2
Over 20,000	21	1	8	11	1
Total	299	56	102	136	5

USE OF EXHAUST STEAM

If exhaust steam from the engine is allowed to escape unused a valuable by-product is wasted and the coal bill is correspondingly high. Exhaust steam can be used successfully for pasteurizing milk or cream, heating boiler-feed water and water for washing purposes, and heating the building. By using an exhaust-steam water heater an abundant supply of water at a temperature of about 200° F. is made available. In case the water from the heater is too hot for the type of pasteurizer used, the temperature may be regulated automatically.

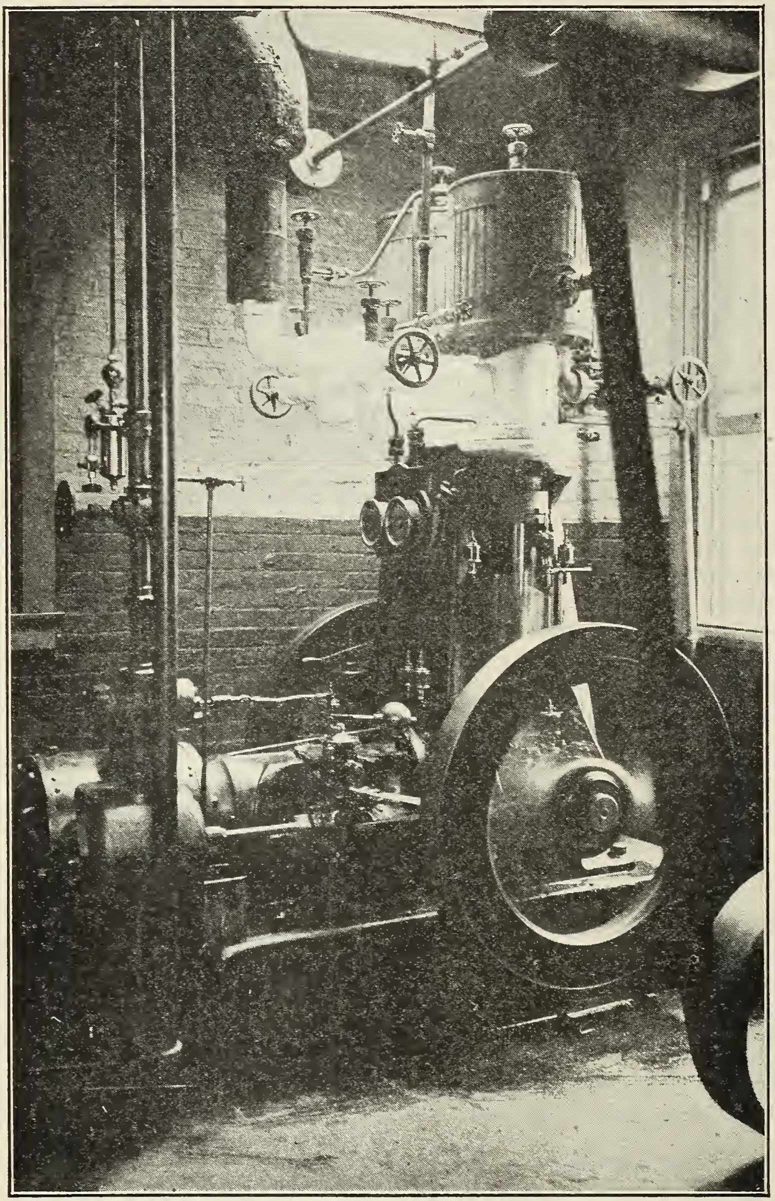

FIGURE 18.—Compression type of refrigerating machine

If a plant has an engine and in pasteurizing uses the exhaust steam instead of live steam direct from the boiler the cost of the steam for heating the milk and pasteurizing is practically eliminated. Generally the exhaust from the engine will furnish all the necessary heat. Therefore, in figuring the size of the boiler required, at a plant using an engine to run the pasteurizers, bottle washers, and other apparatus required in the ordinary retail milk plant, the amount of steam to run the engine only need be considered if the exhaust is utilized for pasteurizing.

To heat 300 gallons of milk from 60° to 145° F. requires about 30 pounds of coal, and with that quantity of milk handled daily an exhaust-steam heater would effect an annual saving of more than 5 tons of coal. This saving would be considerable in a year in a larger plant.

The water used in cooling the milk should be saved. By piping the water back to the heater or to a tank not only will the water itself be saved but also a considerable quantity of coal. Much water in a milk plant can be used several times and in this way the full benefit obtained from the water and the heat it contains.

EQUIPMENT REQUIRED FOR VARIOUS-SIZED PLANTS

On the following pages are lists of the principal equipment required for plants of various sizes and the approximate total cost. These figures on cost are given only as a guide for comparison. The cost of equipment will depend a great deal on the type of machinery selected, kind of contract made, and the character of the business. As prices are continually changing, only approximations can be made as to the cost of equipment. The number of milk cans and bottle cases required will depend upon the individual plant, but in these lists is given the approximate quantity that would be needed.

PRINCIPAL EQUIPMENT FOR PLANT OF 100 GALLONS CAPACITY

One platform scales (double beam).
One pasteurizer (100-gallon vat).
One temperature recorder.
One sanitary milk pump.[6]
Sanitary piping and fittings.
One tubular milk cooler (capacity 1,500 pounds an hour).
One bottle filler.
One turbine-brush bottle washer with tank, rinser, and steamer.
One can wash sink with steam jet.
One small separator.
One small churn.
Milk cans (for delivery to wholesale trade).
Two sets of bottle cases.
One brine tank.
One brine pump.
One 3-horsepower motor.
One 10-horsepower boiler.
Steam and water hose and fittings; shafting, belting, pulleys, hangers, piping, fittings, etc.
Babcock tester (12-bottle size).

Estimated total cost of the plant equipment, from $2,500 to $3,000.

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[6] The number of pumps required will depend on the plant layout.

An initial supply of about 3,000 bottles, also bottle caps, washing powder, and coal will be necessary.

PRINCIPAL EQUIPMENT FOR PLANT OF 500 GALLONS CAPACITY

One platform scales (beam or dial type).
One weigh can, with cover, strainers, and splash hood.
One receiving vat (capacity 150 gallons), with cover, strainer, and agitator. (If vat pasteurizers are used, a receiving vat of less capacity could be used.)
One filter.
One pasteurizing and cooling outfit, with automatic temperature control and recording thermometers.
One or two sanitary milk pumps.[7]
One bottle filler.
One small bottle washer and sterilizer.
One can washer, rinser, and steamer.
One separator (capacity 2,000 to 2,500 pounds per hour).
One small churn and butterworker.
One brine tank.
One brine pump.
Milk cans.
Two sets of bottle cases.
Trucks, conveyors, etc.
One 5-horsepower motor.
One 20-horsepower boiler.
Sanitary milk piping and fittings.
Belting, shafting, pulleys, hangers, piping, fittings, etc.
Steam and water hose with fittings.
Chemical apparatus.

Estimated total cost, from $8,000 to $10,000.

If mechanical refrigeration is used, an additional investment of $1,500 to $2,000 will be required.

An initial supply of about 15,000 bottles, also bottle caps, coal, and washing powder, will be necessary.

PRINCIPAL EQUIPMENT FOR PLANT OF FROM 1,000 TO 1,500 GALLONS CAPACITY

One 2-compartment dump and weigh can, with cover, strainer, splash hood, and two 3-inch gates.
One scales (beam or dial type).
One or two sanitary milk pumps.[8]
One receiving vat (capacity 300 gallons), with cover, strainer, and agitator.
One milk-storage tank (1,000 gallons capacity).
Pasteurizing and cooling outfit, with automatic temperature control and recording thermometers (capacity, 4,000 pounds an hour).
One clarifier or filter (4,000 to 6,000 pounds an hour).
Sanitary milk piping and fittings.
One filler and capper.
One small filler for buttermilk.
One bottle washer (48 to 60 bottles per minute).
One can washer, rinser, steamer, and drier.
One separator (2,000 to 2,500 pounds per hour).
One 50-gallon cream vat.
One buttermilk vat.
One churn and butterworker, butter printer, ladles, packer, and starter can.
Milk cans.
Milk-bottle cases.
Trucks, conveyors, etc.
One 20-ton mechanical refrigeration plant, with compressor, brine tank, piping, brine pump, etc.
One 20-horsepower engine, or motors (if electric power is available).

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[7] The number of pumps required will depend on the plant layout and on the type of pasteurizing equipment used.

[8] See footnote 7.

One 60-horsepower boiler with all necessary fittings and accessories (allowing three hours to pasteurize and cool 1,200 gallons milk).

Shafting, pulleys, belting, hangers, piping, pipe fittings, valves, etc. (If live steam were used for pasteurizing the boiler capacity would have to be increased.)

Chemical apparatus.

Bacteriological apparatus.

Estimated total cost, from $25,000 to $30,000.

PRINCIPAL EQUIPMENT FOR PLANT OF APPROXIMATELY 5,000 GALLONS CAPACITY

One 2-compartment dump and weigh can, with cover, strainers, splash hood, and two 4-inch gates.

One scales (overhead lever type).

One receiving vat, with cover, agitator (motor drive), and strainer (capacity, 300 to 500 gallons).

One or two clarifiers or filters (12,000 pounds an hour combined capacity).

One or two jacketed storage tanks (about 2,500 gallons each).[9]

Pasteurizing and cooling equipment (10,000 pounds an hour), with automatic temperature regulator and recording thermometers.

One small pasteurizer for cream.

One small tubular cooler for cream.

Two or more sanitary milk pumps.[10]

Sanitary milk piping and fittings.

Three fillers and cappers.

One small filler for buttermilk, etc.

One or two bottle washers (80 to 120 bottles per minute).

One can washer, rinser, steamer, and drier.

One forewarmer.

One separator (capacity, 8,000 to 12,000 pounds an hour).

One 300-gallon jacketed vat.

One rotary pump for skim milk.

One combined churn and butterworker (capacity, 1,000 pounds butter), butter printer, ladles, packers, etc.

Milk cans and bottle cases.

Trucks and conveyors.

One starter can.

One 300-gallon ripener.

One 500-gallon standardizing and mixing vat.

One 300-gallon cheese vat.

Two drain racks.

One buttermilk machine (300 gallons capacity) (motor drive).

One 50-ton mechanical refrigeration plant, with compressor, brine tank, piping, brine pump, etc.

One 60-horsepower engine, or 70-horsepower motor, to run compressor.

Two 125-horsepower boilers (one in reserve), with all necessary accessories and fittings (5,000 gallons of milk to be pasteurized at the rate of 10,000 pounds an hour in from four to four and one half hours).

One 25-horsepower engine, or motors.

Belting, shafting, pulleys, hangers, piping, pipe fittings, valves, etc.

Chemical apparatus.

Bacteriological apparatus.

Estimated total cost, from $70,000 to $80,000.

A homogenizer or viscolizer for special coffee cream might be included at an additional cost of $1,500 to $2,500.

BACTERIOLOGICAL APPARATUS FOR MILK PLANT

One autoclave, medium size.

One dry-sterilizing oven, gas stove, and kitchen oven.

One incubator, 10 by 8 by 6 inches, inside dimensions.

One balance, with weights to 5 kilos.

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[9] The capacity of the receiving vat and the number of storage tanks required will depend on how the milk comes in and the system of pasteurization used.

[10] See footnote 7.

One hundred 1-cubic-centimeter pipettes, graduated in tenths, with an extra tenth above the 0 mark.
One 5-cubic-centimeter pipette.
One 10-cubic-centimeter pipette.
One 25-cubic-centimeter pipette.
One 100-cubic-centimeter pipette.
One 100-cubic-centimeter cylinder, graduated.
One 500-cubic-centimeter cylinder, graduated.
One 1,000-cubic-centimeter cylinder, graduated.
Two dozen Erlenmyer flasks, 1,000 cubic-centimeters.
One hundred Petri dishes, 100 by 10 millimeters.
Four dozen glass bottles, 8 ounces, prescription or French square.
Two funnels, glass, 6-inch.
One double boiler, one-half-gallon.
One thermometer (—10° to 100° C.).
One thermometer (0° to 250° C. for dry sterilizer).
One dozen glass stirring rods (assorted).
Two Petri dish holders, sheet iron, 50 dishes.
Two pipette boxes.
One reading glass, 2½ magnifications, 4 inches.
One counting plate.
One tallying machine.
One gas stove, single burner.
Two Bunsen burners.
Twelve feet gas tubing, ¼-inch.
Two wax pencils, blue or red.

Approximate cost, $500.

CHEMICALS AND ACCESSORIES FOR BACTERIOLOGICAL EXAMINATION

One liter sodium hydroxide, tenth normal.
One liter sodium hydroxide, normal.
One liter hydrochloric acid, tenth normal.
One liter hydrochloric acid, normal.
Absorbent cotton.
Nonabsorbent cotton.
Canton flannel for filtering.
Filter papers.
Peptone.

CHEMICAL APPARATUS FOR A MILK-PLANT LABORATORY

One Babcock milk tester from 12 to 36 bottles, hand or steam operated.
Three dozen milk-test bottles, 8 per cent.
One dozen cream-test bottles, 50 per cent.
Two pipettes, 17.6 cubic centimeters.
One combined acid bottle and pipette.
One lactometer (Quevenne).
One burette, 50 cubic centimeters, graduated in tenths.
One burette holder.
One dozen beakers, 150 cubic centimeters.
One dropping bottle, 30 cubic centimeters.
One cream-test scale.
One pipette, 10 cubic centimeters.
One pipette, 25 cubic centimeters.
One-half dozen skim-milk test bottles.

Approximate total cost, from $75 to $100.

CHEMICALS FOR CHEMICAL ANALYSIS OF MILK AND CREAM

Sulphuric acid, commercial, one-half gallon.
Phenolphthalein, 1 per cent solution, 100 cubic centimeters.
Sodium hydroxide, tenth normal, 1 liter.

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